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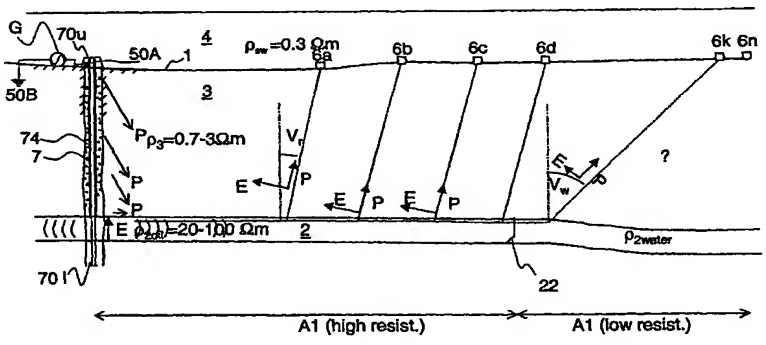
(54) Title: A METHOD FOR MONITORING A HIGH-RESISTIVITY RESERVOIR ROCK FORMATION



(57) Abstract: A method for monitoring a high-resistivity reservoir rock formation (2) below one or more less resistive formations (3), comprising the following steps: Transmitting an electromagnetic signal (S) propagating from near a seafloor or land surface (1) by means of an electromagnetic transmitter (5) powered by a voltage signal generator (G). The electromagnetic signal (S) propagates from the seafloor (1) and is guided along a conductive string (7) to the high-resistive formation (2), and propagates as a guided-wave electromagnetic signal (S_2) at a relatively higher speed (V_2) inside the high-resistivity formation (2) than a propagation speed (V_3) in the less resistive formations (3). The guided-wave electromagnetic signal (S_2) gives rise to an upward refracting electromagnetic signal (R_3) having the relatively lower propagation speed (V_3) in the less resistive formations (3) and having an exit angle nearer to the normal N to the interface between said high-resistivity formation (2) and the lower-resistivity formation (3), and gives rise to a steeply rising refraction wave front (F_3). The refracted electromagnetic wave front (F_3) comprising refracted electromagnetic signals (R_3) is detected along an array of sensor antennas (6a, 6b, 6c, ..., 6k, ..., 6n) along the seafloor, the array having a direction away from the transmitter (5). In a preferred embodiment of the invention, the electromagnetic transmitter (5) comprises an antenna (50) transmitting the electromagnetic signal (S) to an upper end (70 U) of an electrically conductive string (7), e.g. a steel casing or liner, the upper end (70 U) being arranged near said seafloor (1).

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NO 2004/000079

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: G01V 3/12, G01V 3/30
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: G01V

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL,WPI,PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 0000849 A3 (DEN NORSKE STATS OLJESELSKAP A.S.), 6 January 2000 (06.01.2000), page 3, line 8 - line 37, figure 2 --	1-16
X	US 2003011371 A1 (RICHARD A. ROSTHAL ET AL), 16 January 2003 (16.01.2003), [0004],[0034],[0043], [0067] --	1-16
A	US 3440523 A (R. GABILLARD), 22 April 1969 (22.04.1969), column 3, line 13 - line 15; column 4, line 65 - line 75; column 6, line 20 - line 32 --	1-16

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
20 Sept 2004	21 -09- 2004
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Anna Lundqvist/itw Telephone No. +46 8 782 25 00

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/NO 2004/000079

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6366858 B1 (S. MARK HAUGLAND), 2 April 2002 (02.04.2002), see whole document -- --------	1-16

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NO 2004/000079

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see extra sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-16

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NO 2004/000079

The present application relates to 2 different inventions. The separate inventions are:

Invention 1: Claims 1-16 relate to a method for monitoring a high-resistivity reservoir rock formation below one or more less resistive formation. An electromagnetic signal is guided along a conductive string in a well and further propagatinq as a guided-wave electromagnetic signal inside said high-resistivity formation.

Invention 2: Claims 17 relate to a method for stimulating petroleum production from a high-resistivity reservoir rock formation below one or more less resistive formations by injecting energy into the reservoir. The energy is heating the fluids to decrease the viscosity and thus increasing the mobility of the petroleum fluids.

The special technical feature of invention 1 is to let a metallic casing help to guide parts of the EM energy from the surface, through conductive overburden, deeply down into a high-resistivity hydrocarbon reservoir.

The special technical feature of invention 2 is to provide an enhanced production of petroleum.

The single general concept of the present application is to let a metallic casing help to guide parts of EM energy from a surface deep down into a reservoir.

However, this concept is well-known from the prior art since WO 0000849 discloses logging of a petroleum well by means of guided electromagnetic waves. What is being logged is electrical properties and changes in these, preferably in rocks situated along a metallic string in a drilled well. This is a device for detection of changes in resistivity or dielectrical properties due to changes of fluid composition in the near-well area 0-500 m about a well in a geological formation, comprising an electrically conductive tubing string, e. g. a liner pipe or other fixedly mounted tube or open hole completion in the well. See for instance page 3, lines 8-37 and figure 2.

Since the concept is known, it cannot be inventive. Hence, there is no single general inventive concept in the sense of Rule 13.1 PCT.

No other features can be distinguished which can be considered as same or corresponding special technical features in the sense of Rule 13.2 PCT.

Thus, the application lacks unity of invention.

WO	0000849	A3	06/01/2000	AU	5538299 A	17/01/2000
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